Package ‘DelayedTensor’

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**Type**  Package

**Title**  R package for sparse and out-of-core arithmetic and decomposition of Tensor

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**Description**  DelayedTensor operates Tensor arithmetic directly on DelayedArray object. DelayedTensor provides some generic function related to Tensor arithmetic/decomposition and dispatches it on the DelayedArray class. DelayedTensor also supports Tensor contraction by einsum function, which is inspired by numpy einsum.

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Description

DelayedTensor operates Tensor arithmetic directly on DelayedArray object. DelayedTensor provides some generic function related to Tensor arithmetic/decomposition and dispatches it on the DelayedArray class. DelayedTensor also supports Tensor contraction by einsum function, which is inspired by numpy einsum.

Details

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Index: This package was not yet installed at build time.

Author(s)

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See Also

# Unfold operations unfold, k_unfold, matvec, rs_unfold, cs_unfold, ttl
# Fold operations fold, k_fold, unmatvec, rs_fold, cs_fold, ttm
# Vectorization vec
# Norm operations fnorm, innerProd
# Diagonal operations / Diagonal Tensor diag, DelayedDiagonalArray
# Mode-wise operations modeSum, modeMean
# Tensor product operations hadamard, hadamard_list, kronecker, kronecker_list, khatri_rao, khatri_rao_list
# Utilities list_rep, modebind_list, rbind_list, cbind_list
# Decomposition operations hosvd, cp, tucker, mPCA, pvd
# Einsum operation einsum

Examples

ls("package:DelayedTensor")

cbind_list L

Description

Returns the binded DelayedArray in column space.

Usage

cbind_list(L)
Arguments

\[
\text{L}
\]
list of 2D DelayedArray

Details

This is a wrapper function to `modebind_list`, when the DelayedArrays are 2D.

Value

2D DelayedArray object

Note

The dimensions of column in each DelayedArray must match.

See Also

`modebind_list`

Examples

```r
library("DelayedRandomArray")
dlizt <- list(
  'darr1' = RandomUnifArray(c(2,3)),
  'darr2' = RandomUnifArray(c(2,3)))
cbind_list(dlizt)
```

Description

Canonical Polyadic (CP) decomposition of a tensor, aka CANDECOMP/PARAFAC. Approximate a K-Tensor using a sum of `num_components` rank-1 K-Tensors. A rank-1 K-Tensor can be written as an outer product of K vectors. There are a total of `num_components`*\text{darr}@\text{num_modes}` vectors in the output, stored in `darr@num_modes` matrices, each with `num_components` columns. This is an iterative algorithm, with two possible stopping conditions: either relative error in Frobenius norm has gotten below `tol`, or the `max_iter` number of iterations has been reached. For more details on CP decomposition, consult Kolda and Bader (2009).

Usage

```r
cp(darr, num_components=NULL, max_iter=25, tol=1e-05)
```
**cp-methods**

**Arguments**

- `darr` Tensor with K modes
- `num_components` the number of rank-1 K-Tensors to use in approximation
- `max_iter` maximum number of iterations if error stays above `tol`
- `tol` relative Frobenius norm error tolerance

**Details**

This function is an extension of the *cp* by DelayedArray.

Uses the Alternating Least Squares (ALS) estimation procedure. A progress bar is included to help monitor operations on large tensors.

**Value**

A list containing the following:

- `lambdas` a vector of normalizing constants, one for each component
- `U` a list of matrices - one for each mode - each matrix with `num_components` columns
- `conv` whether or not `resid < tol` by the last iteration
- `norm_percent` the percent of Frobenius norm explained by the approximation
- `est` estimate of `darr` after compression
- `fnorm_resid` the Frobenius norm of the error `fnorm(est-darr)`
- `all_resids` vector containing the Frobenius norm of error for all the iterations

**References**


**See Also**

- `tucker`

**Examples**

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(3,4,5))
.cp(darr, num_components=2)
```
Description

The inverse operation to \texttt{cs_unfold}.

Usage

\begin{verbatim}
\texttt{cs_fold(mat, m = NULL, modes = NULL)}
\end{verbatim}

\begin{verbatim}
# S4 method for signature 'DelayedArray'
\texttt{cs_fold(mat, m, modes)}
\end{verbatim}

Arguments

- \texttt{mat}DelayedArray object (only 2D)
- \texttt{m}the mode corresponding to \texttt{cs_unfold}
- \texttt{modes}the original modes of the DelayedArray

Details

This function is an extension of the \texttt{cs_fold} by DelayedArray. This is a wrapper function to \texttt{fold}.

Value

DelayedArray (higher than 2D)

References


See Also

\texttt{fold, cs_unfold}

Examples

\begin{verbatim}
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
matT3 <- DelayedTensor::cs_unfold(darr, m=3)
identical(
    as.array(DelayedTensor::cs_fold(matT3, m=3, modes=c(2,3,4))),
    as.array(darr))
\end{verbatim}
Description

Please see `matvec` and `unfold`.

Usage

```r
cs_unfold(darr, m)
```

## S4 method for signature 'DelayedArray'
cs_unfold(darr, m)

Arguments

- `darr`: DelayedArray object
- `m`: mode to be unfolded on

Details

This function is an extension of the `cs_unfold` by DelayedArray.

This is a wrapper function to `unfold`.

Value

DelayedArray (2D)

See Also

`unfold`, `cs_fold`

Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
DelayedTensor::cs_unfold(darr, m=3)
```
DelayedDiagonalArray  

Description

Constructor of the diagonal of a DelayedArray.

Usage

DelayedDiagonalArray(shape, value)

Arguments

- shape: Shape of DelayedArray (mode of Tensor)
- value: either a single value or a vector. This argument is optional. If nothing is specified, 1s are filled with each diagonal element.

Details

See also `diag` or `diag`.

Value

DelayedArray object

References


See Also

`diag`, `diag`

Examples

darr <- DelayedDiagonalArray(2:4, 5)
DelayedTensor::diag(darr)
**Description**

Extract or replace the diagonal of a DelayedArray, or substitute the elements to the diagonal DelayedArray.

**Usage**

```r
diag(darr)
diag(darr) <- value
```

```r
## S4 method for signature 'DelayedArray'
diag(darr)
## S4 replacement method for signature 'DelayedArray'
diag(darr) <- value
```

**Arguments**

- `darr` DelayedArray object
- `value` either a single value or a vector of length equal to that of the current diagonal. Should be of a mode which can be coerced to that of `darr`.

**Details**

See also `DelayedDiagonalArray` or `diag`.

**Value**

1D DelayedArray (vector) with length `min(dim(darr))`

**References**


**See Also**

`DelayedDiagonalArray`

**Examples**

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
DelayedTensor::diag(darr)
DelayedTensor::diag(darr)[1] <- 11111
DelayedTensor::diag(darr)[2] <- 22222
DelayedTensor::diag(darr)
```
Einsum

Einsum Summation of DelayedArray

Description

Einstein summation is a convenient and concise notation for operations on n-dimensional arrays.

NOTE: Sparse mode of einsum is not available for now.

Usage

```r
einsum(subscripts, ...)  
```

Arguments

- `subscripts`: a string in Einstein notation where arrays are separated by ',' and the result is separated by '->'. For example "ij,jk->ik" corresponds to a standard matrix multiplication. Whitespace inside the subscripts is ignored. Unlike the equivalent functions in Python, einsum only supports the explicit mode. This means that the subscripts must contain '->'.

... the DelayedArrays that are combined.

Details

This function is an extension of the `einsum` by DelayedArray.

Value

The einsum function returns an array with one dimension for each index in the result of the subscripts. For example "ij,jk->ik" produces a 2-dimensional array. "abc,cd,de->abe" produces a 3-dimensional array.

Examples

```r
library("DelayedArray")
library("DelayedRandomArray")
darr1 <- RandomUnifArray(c(4,8))
darr2 <- RandomUnifArray(c(8,3))

# Matrix Multiply
darr1  %%  barr2
DelayedTensor::einsum("ij,jk -> ik", darr1, darr2)

# Diag
mat_sq <- RandomUnifArray(c(4,4))
DelayedTensor::diag(mat_sq)
einsum("ii->i", mat_sq)

# Trace
```
fnorm-methods

```
sum(DelayedTensor::diag(mat_sq))
einsum("ii->", mat_sq)

# Scalar product
darr3 <- RandomUnifArray(c(4,8))
darr3 * darr1
einsum("ij,ij->ij", darr3, darr1)

# Transpose
t(darr1)
einsum("ij->ji", darr1)

# Batched L2 norm
arr1 <- as.array(darr1)
arr3 <- as.array(darr3)
darr4 <- DelayedArray(array(c(arr1, arr3), dim = c(dim(arr1), 2)))
c(sum(darr1^2), sum(darr3^2))
einsum("ijb,ijb->b", darr4, darr4)
```

---

**fnorm-methods**

*Tensor Frobenius Norm of DelayedArray*

**Description**

Returns the Frobenius norm of the Tensor instance.

**Usage**

```
fnorm(darr)
```

```r
## S4 method for signature 'DelayedArray'
fnorm(darr)
```

**Arguments**

- `darr` DelayedArray object

**Details**

This function is an extension of the `fnorm` by DelayedArray.

**Value**

numeric Frobenius norm of `darr`

**Examples**

```
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
fnorm(darr)
```
Description

General folding of a 2D DelayedArray into a higher-order DelayedArray(Tensor). This is designed to be the inverse function to `unfold`, with the same ordering of the indices. This amounts to following: if we were to unfold a Tensor using a set of `row_idx` and `col_idx`, then we can fold the resulting matrix back into the original Tensor using the same `row_idx` and `col_idx`.

Usage

```r
fold(mat, row_idx = NULL, col_idx = NULL, modes = NULL)
```

## S4 method for signature 'DelayedArray'
fold(mat, row_idx, col_idx, modes)

Arguments

- `mat`: DelayedArray object (only 2D)
- `row_idx`: the indices of the modes that are mapped onto the row space
- `col_idx`: the indices of the modes that are mapped onto the column space
- `modes`: the modes of the output DelayedArray

Details

This function is an extension of the `fold` by DelayedArray.

Value

DelayedArray object with modes given by `modes`

References


See Also

`unfold`, `k_fold`, `unmatvec`, `rs_fold`, `cs_fold`
getSparse

Examples

library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
matT3 <- DelayedTensor::unfold(darr, row_idx=2, col_idx=c(3,1))
identical(
  as.array(DelayedTensor::fold(matT3, row_idx=2,col_idx=c(3,1),
    modes=c(2,3,4)) ),
  as.array(darr))

getSparse  Getter of the intermediate/output DelayedArray object in DelayedTensor

Description
Whether the intermediate and output DelayedArray used in DelayedTensor is used as sparse tensor or not.

NOTE: Sparse mode is experimental! Whether it contributes to higher speed and lower memory is quite dependent on the sparsity of the DelayedArray, and the current implementation does not recognize the block size, which may cause Out-of-Memory errors.

Usage
getSparse()

Value
TRUE or FALSE (Default: FALSE)

Examples
getSparse()

getVerbose  Getter function to control the verbose messages from DelayedTensor

Description
Returns the verbose setting of DelayedTensor functions.

Usage
getVerbose()

Value
TRUE or FALSE (Default: FALSE)
Examples

getVerbose()

hadamard-methods Hadamard Product of DelayedArray

Description

Returns the Hadamard product of two Tensors. Commonly used for n-mode products and various Tensor decompositions.

Usage

hadamard(darr1, darr2)

## S4 method for signature 'DelayedArray,DelayedArray'
hadamard(darr1, darr2)

Arguments

darr1 first DelayedArray object
darr2 second DelayedArray object

Value

matrix that is the Hadamard product

Note

The modes/dimensions of each element of two Tensors must match.

See Also

khatri_rao, khatri_rao_list, kronecker, kronecker_list, hadamard_list

Examples

library("DelayedRandomArray")
darr1 <- RandomUnifArray(c(2,4))
darr2 <- RandomUnifArray(c(2,4))
hadamard(darr1, darr1)
hadamard_list

| hadamard_list | Hadamard Product against list |

Description

Returns the hadamard (element-wise) product from a list of matrices or vectors. Commonly used for n-mode products and various Tensor decompositions.

Usage

```r
hadamard_list(L)
```

Arguments

- `L` list of DelayedArray

Details

This function is an extension of the `hadamard_list` by DelayedArray.

Value

matrix that is the Hadamard product

Note

The modes/dimensions of each element in the list must match.

See Also

- `khatri_rao`, `khatri_rao_list`, `kronecker`, `kronecker_list`, `hadamard`

Examples

```r
library("DelayedRandomArray")
dlizt <- list(
  'darr1' = RandomUnifArray(c(2,3,4)),
  'darr2' = RandomUnifArray(c(2,3,4)))
hadamard_list(dlizt)
```
(Truncated-)Higher-order SVD

Description

Higher-order SVD of a K-Tensor. Write the K-Tensor as a (m-mode) product of a core Tensor (possibly smaller modes) and K orthogonal factor matrices. Truncations can be specified via ranks (making them smaller than the original modes of the K-Tensor will result in a truncation). For the mathematical details on HOSVD, consult Lathauwer et. al. (2000).

Usage

hosvd(darr, ranks=NULL)

## S4 method for signature 'DelayedArray'

hosvd(darr, ranks)

Arguments

darr Tensor with K modes
ranks a vector of desired modes in the output core tensor, default is darr@modes

Details

This function is an extension of the hosvd byDelayedArray.

A progress bar is included to help monitor operations on large tensors.

Value

a list containing the following:

Z core tensor with modes specified by ranks
U a list of orthogonal matrices, one for each mode
est estimate of darr after compression
fnorm_resid the Frobenius norm of the error fnorm(est-darr) - if there was no truncation, then this is on the order of mach_eps * fnorm.

Note

The length of ranks must match darr@num_modes.

References

**human_mid_brain**

**See Also**

`tucker`

**Examples**

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(3,4,5))
hosvd(darr, ranks=c(2,1,3))
```

---

**human_mid_brain**

*Matrix object of human mid brain data*

**Description**

A matrix with 500 rows (genes) * 1977 columns (cells).

**Usage**

```r
data(human_mid_brain)
```

**Details**


For the details, see inst/script/make-data.R.

**References**


**See Also**

`mouse_mid_brain`

**Examples**

```r
data(human_mid_brain)
```
**innerProd-methods**  
*Tensors Inner Product of DelayedArray*

**Description**

Returns the inner product between two Tensors

**Usage**

```r
innerProd(darr1, darr2)
```

```r
## S4 method for signature 'DelayedArray',DelayedArray
innerProd(darr1, darr2)
```

**Arguments**

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>darr1</td>
<td>first DelayedArray object</td>
</tr>
<tr>
<td>darr2</td>
<td>second DelayedArray object</td>
</tr>
</tbody>
</table>

**Details**

This function is an extension of the `innerProd` by DelayedArray.

**Value**

inner product between darr1 and darr2

**Examples**

```r
library("DelayedRandomArray")
darr1 <- RandomUnifArray(c(2,3,4))
darr2 <- RandomUnifArray(c(2,3,4))
innerProd(darr1, darr2)
```

**khatri_rao-methods**  
*Khatri-Rao Product of DelayedArray*

**Description**

Returns the Khatri-Rao (column-wise Kronecker) product of two matrices. If the inputs are vectors then this is the same as the Kronecker product.

**Usage**

```r
khatri_rao(darr1, darr2)
```

```r
## S4 method for signature 'DelayedArray',DelayedArray
khatri_rao(darr1, darr2)
```

**Examples**

```r
library("DelayedRandomArray")
darr1 <- RandomUnifArray(c(2,3,4))
darr2 <- RandomUnifArray(c(2,3,4))
khatri_rao(darr1, darr2)
```
Arguments

- darr1: first DelayedArray object
- darr2: second DelayedArray object

Details

This function is an extension of the `khatri_rao` by DelayedArray.

Value

Matrix that is the Khatri-Rao product

Note

The number of columns must match in the two inputs.

See Also

- `hadamard`
- `hadamard_list`
- `kronecker`
- `kronecker_list`
- `khatri_rao_list`

Examples

```r
library("DelayedRandomArray")
darr1 <- RandomUnifArray(c(2,4))
darr2 <- RandomUnifArray(c(3,4))
khatri_rao(darr1, darr2)
```

Description

Returns the Khatri-Rao product from a list of matrices or vectors. Commonly used for n-mode products and various Tensor decompositions.

Usage

`khatri_rao_list(L, reverse = FALSE)`

Arguments

- L: list of DelayedArray
- reverse: whether or not to reverse the order

Details

This function is an extension of the `khatri_rao_list` by DelayedArray.
Kronecker Product of DelayedArray

Kronecker Product of DelayedArray

Description

Returns the Kronecker product of two Tensors. Commonly used for n-mode products and various Tensor decompositions.

Usage

kronecker(darr1, darr2)

## S4 method for signature 'DelayedArray,DelayedArray'
kron economical(darr1, darr2)

Arguments

darr1 first DelayedArray object
darr2 second DelayedArray object

Value

matrix that is the Kronecker product

See Also

khatri_rao, khatri_rao_list, hadamard, hadamard_list, kronecker_list
kronecker_list

Examples

library("DelayedRandomArray")
darr1 <- RandomUnifArray(c(2,3))
darr2 <- RandomUnifArray(c(4,5))
kronecker(darr1, darr2)

Description

Returns the Kronecker product from a list of matrices or vectors. Commonly used for n-mode products and various Tensor decompositions.

Usage

kronecker_list(L)

Arguments

L

list of DelayedArray

Details

This function is an extension of the kronecker_list by DelayedArray.

Value

matrix that is the Kronecker product

See Also

khatri_rao, khatri_rao_list, hadamard, hadamard_list, kronecker

Examples

library("DelayedRandomArray")
dlizt <- list(
  'darr1' = RandomUnifArray(c(2,3,4)),
  'darr2' = RandomUnifArray(c(2,3,4)))
kronecker_list(dlizt)
Description

k-mode folding of a matrix into a Tensor. This is the inverse function to \texttt{k_unfold} in the m mode. In particular, \texttt{k\_fold(k\_unfold(darr, m), m, dim(darr))} will result in the original Tensor.

Usage

\begin{verbatim}
k_fold(mat, m = NULL, modes = NULL)
## S4 method for signature 'DelayedArray'
k_fold(mat, m, modes)
\end{verbatim}

Arguments

\begin{itemize}
\item \texttt{mat} \hspace{1cm} \text{DelayedArray object (only 2D)}
\item \texttt{m} \hspace{1cm} \text{the index of the mode that is mapped onto the row indices}
\item \texttt{modes} \hspace{1cm} \text{the modes of the output DelayedArray}
\end{itemize}

Details

This function is an extension of the \texttt{k\_fold} by DelayedArray. This is a wrapper function to \texttt{fold}.

Value

\text{DelayedArray object with modes given by modes}

References


See Also

\texttt{fold, k\_unfold}

Examples

\begin{verbatim}
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
matT2 <- k_unfold(darr, m=2)
identical(
    as.array(k_fold(matT2, m=2, modes=c(2,3,4))),
    as.array(darr))
\end{verbatim}
**k_unfold-methods**

**Tensor k-mode Unfolding of DelayedArray**

### Description

Unfolding of a tensor by mapping the kth mode (specified through parameter m), and all other modes onto the column space. This the most common type of unfolding operation for Tucker decompositions and its variants. Also known as k-mode matricization.

### Usage

```
k_unfold(darr, m)
```

### Arguments

- `darr`: DelayedArray object
- `m`: the index of the mode to unfold on

### Details

This function is an extension of the `k_unfold` by DelayedArray.

This is a wrapper function to `unfold`.

See also `k_unfold(darr, m=NULL)`

### Value

matrix with `dim(darr)[m]` rows and `prod(dim(darr)[~m])` columns

### References


### See Also

- `unfold`, `k_fold`

### Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
rs_unfold(darr, m=2)
```
**list_rep**  
*Replicate of arbitrary object*

**Description**

Returns the replicates of base object x.

**Usage**

```r
list_rep(x, n=NULL)
```

**Arguments**

- `x` Any object
- `n` Number of replicate

**Value**

List

**Examples**

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
list_rep(darr, 3)
```

---

**matvec-methods**  
*Tensor Matvec Unfolding of DelayedArray*

**Description**

For 3-tensors only. Stacks the slices along the third mode.

**Usage**

```r
matvec(darr)
```

```r
## S4 method for signature 'DelayedArray'
matvec(darr)
```

**Arguments**

- `darr` DelayedArray object
Details

This function is an extension of the `matvec` by DelayedArray. This is a wrapper function to `unfold`.

Value

matrix with \( \text{prod}(\text{dim}(\text{darr})[-m]) \) rows and \( \text{dim}(\text{darr})[m] \) columns

References


See Also

`unfold`, `unmatvec`

Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
matvec(darr)
```

```
modebind_list                      Mode-binding against list

Description

Returns the binded DelayedArray in mode-\( m \).

Usage

`modebind_list(L, m=NULL)`

Arguments

- `L` list of DelayedArray
- `m` list of DelayedArray

Value

DelayedArray object

Note

The dimensions of mode \( m \) must match.
modeMean-methods

Tensor Mean Across Single Mode of DelayedArray

Description

Given a mode for a K-tensor, this returns the K-1 tensor resulting from taking the mean across that particular mode.

Usage

modeMean(darr, m = NULL, drop = FALSE)

## S4 method for signature 'DelayedArray'

modeMean(darr, m, drop)

Arguments

darr        DelayedArray object
m                   the index of the mode to average across
drop            whether or not mode m should be dropped

Details

This function is an extension of the modeMean by DelayedArray.  
NOTE: Sparse mode of modeMean is not available for now.

Value

K-1 or K Tensor, where K = length(dim(darr))

See Also

modeSum
Examples

library("DelayedRandomArray")
darr <- RandomUnifArray(c(1,2,3))
modeMean(darr, 1, drop=FALSE)
modeMean(darr, 1, drop=TRUE)
modeMean(darr, 2)
modeMean(darr, 3)

modeSum-methods  
Tensor Sum Across Single Mode of DelayedArray

Description

Given a mode for a K-tensor, this returns the K-1 tensor resulting from summing across that particular mode.

Usage

modeSum(darr, m = NULL, drop = FALSE)

## S4 method for signature 'DelayedArray'
modeSum(darr, m, drop)

Arguments

darr  
DelayedArray object

m  
the index of the mode to sum across

drop  
whether or not mode m should be dropped

Details

This function is an extension of the modeSum by DelayedArray.

NOTE: Sparse mode of modeSum is not available for now.

modeSum(darr, m=NULL, drop=FALSE)

Value

K-1 or K tensor, where K = length(dim(darr))

See Also

modeMean
Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(1,2,3))
modeSum(darr, 1, drop=FALSE)
modeSum(darr, 1, drop=TRUE)
modeSum(darr, 2)
modeSum(darr, 3)
```

---

**mouse_mid_brain**

*Matrix object of mouse mid brain data*

Description

A matrix with 500 rows (genes) * 1907 columns (cells).

Usage

```r
data(mouse_mid_brain)
```

Details


For the details, see inst/script/make-data.R.

References


See Also

`mouse_mid_brain`

Examples

```r
data(mouse_mid_brain)
```
Description

This is basically the Tucker decomposition of a K-Tensor, `tucker`, with one of the modes uncompressed. If K = 3, then this is also known as the Generalized Low Rank Approximation of Matrices (GLRAM). This implementation assumes that the last mode is the measurement mode and hence uncompressed. This is an iterative algorithm, with two possible stopping conditions: either relative error in Frobenius norm has gotten below `tol`, or the `max_iter` number of iterations has been reached. For more details on the MPCA of tensors, consult Lu et al. (2008).

Usage

```r
mpca(darr, ranks=NULL, max_iter=25, tol=1e-05)
```

## S4 method for signature 'DelayedArray'

```r
mpca(darr, ranks, max_iter, tol)
```

Arguments

- `darr`: Tensor with K modes
- `ranks`: a vector of the compressed modes of the output core Tensor, this has length K-1
- `max_iter`: maximum number of iterations if error stays above `tol`
- `tol`: relative Frobenius norm error tolerance

Details

This function is an extension of the `mpca` by DelayedArray. Uses the Alternating Least Squares (ALS) estimation procedure. A progress bar is included to help monitor operations on large tensors.

Value

a list containing the following:

- `Z_ext`: the extended core tensor, with the first K-1 modes given by `ranks`
- `U`: a list of K-1 orthogonal factor matrices - one for each compressed mode, with the number of columns of the matrices given by `ranks`
- `conv`: whether or not `resid < tol` by the last iteration
- `est`: estimate of `darr` after compression
- `norm_percent`: the percent of Frobenius norm explained by the approximation
- `fnorm_resid`: the Frobenius norm of the error `fnorm(est-darr)`
- `all_resids`: vector containing the Frobenius norm of error for all the iterations
Note

The length of ranks must match darr@num_modes-1.

References


See Also

tucker, hosvd

Examples

library("DelayedRandomArray")
darr <- RandomUnifArray(c(3,4,5))
mpca(darr, ranks=c(1,2))

Description

Returns the outer product between two Tensors

Usage

outerProd(darr1, darr2)

## S4 method for signature 'DelayedArray,DelayedArray'
outerProd(darr1, darr2)

Arguments

darr1 first DelayedArray object
darr2 second DelayedArray object

Details

NOTE: Sparse mode of outerProd is not available for now.

Value

outer product between darr1 and darr2
Examples

```r
library("DelayedRandomArray")
darr1 <- RandomUnifArray(c(2,3))
darr2 <- RandomUnifArray(c(4,5))
outerProd(darr1, darr2)
```

Description

The default Population Value Decomposition (PVD) of a series of 2D images. Constructs population-level matrices P, V, and D to account for variances within as well as across the images. Structurally similar to Tucker (`tucker`) and GLRAM (`mpca`), but retains crucial differences. Requires $2n_3 + 2$ parameters to specified the final ranks of P, V, and D, where $n_3$ is the third mode (how many images are in the set). Consult Crainiceanu et al. (2013) for the construction and rationale behind the PVD model.

Usage

```r
pvd(darr, uranks=NULL, wranks=NULL, a=NULL, b=NULL)
```

Arguments

- `darr`: 3D DelayedArray (Tensor) with the third mode being the measurement mode
- `uranks`: ranks of the U matrices
- `wranks`: ranks of the W matrices
- `a`: rank of $P = U%*%t(U)$
- `b`: rank of $D = W%*%t(W)$

Details

This function is an extension of the `pvd` by DelayedArray.

The PVD is not an iterative method, but instead relies on $n_3 + 2$ separate PCA decompositions. The third mode is for how many images are in the set.

Value

A list containing the following:

- `P`: population-level matrix $P = U%*%t(U)$, where $U$ is constructed by stacking the truncated left eigenvectors of slicewise PCA along the third mode
- `V`: a list of image-level core matrices
D population-level matrix \( D = W^\perp % t(W) \), where \( W \) is constructed by stacking the truncated right eigenvectors of slicewise PCA along the third mode.

- est: estimate of \( darr \) after compression
- norm_percent: the percent of Frobenius norm explained by the approximation
- fnorm_resid: the Frobenius norm of the error \( fnorm(est-darr) \)

### References


### Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(3,4,5))
pvd(darr, uranks=rep(2,5), wranks=rep(3,5), a=2, b=3)
```

### Description

Returns the binded DelayedArray in row space.

### Usage

```r
rbind_list(L)
```

### Arguments

- `L`: list of 2D DelayedArray

### Details

This is a wrapper function to `modebind_list`, when the DelayedArrays are 2D.

### Value

2D DelayedArray object

### Note

The dimensions of row in each DelayedArray must match.

### See Also

`modebind_list`
Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
dlizt <- list(
  'darr1' = RandomUnifArray(c(2,3)),
  'darr2' = RandomUnifArray(c(2,3)))
rbind_list(dlizt)
```

---

**Description**

The inverse operation to `rs_unfold`.

**Usage**

```r
rs_fold(mat, m = NULL, modes = NULL)
```

```r
## S4 method for signature 'DelayedArray'
rs_fold(mat, m, modes)
```

**Arguments**

- `mat`_DelayedArray object (only 2D)
- `m`_the mode corresponding to `rs_unfold`
- `modes`_the original modes of the DelayedArray

**Details**

This function is an extension of the `rs_fold` by DelayedArray.
This is a wrapper function to `fold`.

**Value**

DelayedArray (higher than 2D)

**References**


**See Also**

`fold`, `rs_unfold`
Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
matT2 <- rs_unfold(darr, m=2)
identical(
  as.array(rs_fold(matT2, m=2, modes=c(2,3,4))),
  as.array(darr))
```

Description

Please see `k_unfold` and `unfold`.

Usage

```
rs_unfold(darr, m)
```

## S4 method for signature 'DelayedArray'
rs_unfold(darr, m)

Arguments

- `darr`: DelayedArray object
- `m`: mode to be unfolded on

Details

This function is an extension of the `rs_unfold` by `DelayedArray`
This is a wrapper function to `unfold`
See also `rs_unfold(darr, m=NULL)`

Value

`DelayedArray` (2D)

See Also

`unfold`, `rs_fold`

Examples

```
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
matT2 <- rs_unfold(darr, m=2)
```
**setSparse**

*Setter to set the intermediate DelayedArray object in DelayedTensor*

**Description**

Set whether the intermediate and output DelayedArray used in DelayedTensor is used as sparse tensor or not.

NOTE: Sparse mode is experimental! Whether it contributes to higher speed and lower memory is quite dependent on the sparsity of the DelayedArray, and the current implementation does not recognize the block size, which may cause Out-of-Memory errors.

**Usage**

```r
setSparse(as.sparse=FALSE)
```

**Arguments**

- `as.sparse` TRUE or FALSE (Default: FALSE)

**Value**

Nothing

**Examples**

```r
setSparse(TRUE)
setSparse(FALSE)
```

**setVerbose**

*Setter to set the verbose mode of DelayedTensor*

**Description**

Set the verbose message to monitor the block-processing procedure.

**Usage**

```r
setVerbose(as.verbose=FALSE)
```

**Arguments**

- `as.verbose` TRUE or FALSE (Default: FALSE)

**Value**

Nothing
Examples

```r
setVerbose(TRUE)
setVerbose(FALSE)
```

---

### ttl

#### DelayedArray Times List

**Description**

Contracted (m-Mode) product between a Tensor of arbitrary number of modes and a list of matrices. The result is folded back into Tensor.

**Usage**

```r
ttl(darr, list_mat, ms=NULL)
```

**Arguments**

- `darr`: DelayedArray object with K modes
- `list_mat`: a list of 2D DelayedArray objects
- `ms`: a vector of modes to contract on (order should match the order of `list_mat`)

**Details**

This function is an extension of the `ttl` by DelayedArray.

This is a wrapper function to `unfold`.

Performs `ttm` repeated for a single Tensor and a list of matrices on multiple modes. For instance, suppose we want to do multiply a Tensor object `darr` with three matrices `mat1`, `mat2`, `mat3` on modes 1, 2, and 3. We could do `ttm(ttm(ttm(darr,mat1,1),mat2,2),3)`, or we could do `ttl(darr,list(mat1,mat2,mat3),c(1,2,3))`. The order of the matrices in the list should obviously match the order of the modes. This is a common operation for various Tensor decompositions such as CP and Tucker. For the math on the m-Mode Product, see Kolda and Bader (2009).

**Value**

DelayedArray object with K modes (Tensor)

**Note**

The returned Tensor does not drop any modes equal to 1.

**References**

**ttm-methods**

**See Also**

`ttm`

**Examples**

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(3,4,5))
dlizt <- list(
  'darr1' = RandomUnifArray(c(10,3)),
  'darr2' = RandomUnifArray(c(10,4)))
ttl(darr, dlizt, ms=c(1,2))
```

### Description

Contracted (m-Mode) product between a DelayedArray (Tensor) of arbitrary number of modes and a matrix. The result is folded back into Tensor.

### Usage

```r
ttm(darr, mat, m = NULL)
```

```r
## S4 method for signature 'DelayedArray,DelayedArray'
ttm(darr, mat, m)
```

### Arguments

- `darr`: DelayedArray object
- `mat`: input 2D DelayedArray with same number columns as the mth mode of `darr`
- `m`: the mode to contract on

### Details

This function is an extension of the `ttm` by DelayedArray.

By definition, `rs_unfold(ttm(darr, mat), m) = mat%*%rs_unfold(darr, m)`. so the number of columns in `mat` must match the mth mode of `darr`. For the math on the m-Mode Product, see Kolda and Bader (2009).

### Value

- a DelayedArray object with K modes

### Note

The mth mode of `darr` must match the number of columns in `mat`. By default, the returned Tensor does not drop any modes equal to 1.
References


See Also

rs_unfold, ttl

Examples

library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
mat <- RandomUnifArray(c(10,4))
ttm(darr, mat, m=3)

### S4 method for signature 'DelayedArray'
tucker(darr, ranks, max_iter, tol)

Arguments

darr Tensor with K modes
ranks a vector of the modes of the output core Tensor
max_iter maximum number of iterations if error stays above tol
tol relative Frobenius norm error tolerance

Details

This function is an extension of the tucker by DelayedArray. Uses the Alternating Least Squares (ALS) estimation procedure also known as Higher-Order Orthogonal Iteration (HOOI). Initialized using a (Truncated-)HOSVD. A progress bar is included to help monitor operations on large tensors.
Value

a list containing the following:

- **Z**: the core tensor, with modes specified by `ranks`
- **U**: a list of orthogonal factor matrices - one for each mode, with the number of columns of the matrices given by `ranks`
- **conv**: whether or not `resid < tol` by the last iteration
- **est**: estimate of `darr` after compression
- **norm_percent**: the percent of Frobenius norm explained by the approximation
- **fnorm_resid**: the Frobenius norm of the error `fnorm(est-darr)`
- **all_resids**: vector containing the Frobenius norm of error for all the iterations

Note

The length of `ranks` must match `darr@num_modes`.

References


See Also

hosvd, m pca

Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
tucker(darr, ranks=c(1,2,3))
```

Description

Unfolds the tensor into a matrix, with the modes in `rs` onto the rows and modes in `cs` onto the columns. Note that `c(rs,cs)` must have the same elements (order doesn’t matter) as `dim(darr)`. Within the rows and columns, the order of the unfolding is determined by the order of the modes. This convention is consistent with Kolda and Bader (2009).

Usage

```r
unfold(darr, row_idx, col_idx)
```

### S4 method for signature 'DelayedArray'

```r
unfold(darr, row_idx, col_idx)
```
Arguments

darr        DelayedArray object
row_idx     the indices of the modes to map onto the row space
col_idx     the indices of the modes to map onto the column space

Details

This function is an extension of the unfold by DelayedArray.
For Row Space Unfolding or m-mode Unfolding, see rs_unfold. For Column Space Unfolding or matvec, see cs_unfold.
vec returns the vectorization of the tensor.

Value

2D DelayedArray with prod(row_idx) rows and prod(col_idx) columns

References


See Also

k_unfold, matvec, rs_unfold, cs_unfold

Examples

library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
unfold(darr, row_idx=2, col_idx=c(3,1))

---

unmatvec-methods  Unmatvec Folding of 2D DelayedArray

Description

The inverse operation to matvec-methods, turning a matrix into a Tensor. For a full account of matrix folding/unfolding operations, consult Kolda and Bader (2009).

Usage

unmatvec(mat, modes = NULL)

## S4 method for signature 'DelayedArray'
unmatvec(mat, modes)
Arguments

- **mat**: DelayedArray object (only 2D)
- **modes**: the modes of the output DelayedArray

Details

This function is an extension of the `unmatvec` by `DelayedArray`. This is a wrapper function to `fold`.

Value

DelayedArray object with modes given by `modes`

References


See Also

`fold`, `matvec`

Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
matT1 <- matvec(darr)
identical(
  as.array(unmatvec(matT1, modes=c(2,3,4))),
  as.array(darr))
```

---

vec-methods

Tensor Vectorization of DelayedArray

Description

Change the dimension of DelayedArray from multi-dimension (e.g. array) to single-dimension (e.g. vector).

Usage

```r
vec(darr)
```

```r
# S4 method for signature 'DelayedArray'
vec(darr)
```
Arguments

darr       DelayedArray object

Details

This function is an extension of the `vec` by DelayedArray.

Value

1D DelayedArray (vector) with length `prod(dim(darr))`

References


Examples

```r
library("DelayedRandomArray")
darr <- RandomUnifArray(c(2,3,4))
vec(darr)
```
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